Compliments of
WCR

NATURAL CEMENT VERSUS BRICK; IWAHIG PENAL COLONY RAW MATERIALS

By W. C. REIBLING
(*From the Laboratory of General, Inorganic, and Physical Chemistry, Bureau of Science, Manila, P. I.*)

Reprinted from
THE PHILIPPINE JOURNAL OF SCIENCE
Published by the Bureau of Science of the Philippine Government,
Manila, P. I.
VOL. IX, NO. 2, SEC. A, CHEMICAL AND GEOLOGICAL SCIENCES AND THE INDUSTRIES, APRIL, 1914

MANILA
BUREAU OF PRINTING
1914

126874

NATURAL CEMENT VERSUS BRICK; IWAHIG PENAL COLONY RAW MATERIALS

By W. C. REIBLING

(From the Laboratory of General, Inorganic, and Physical Chemistry, Bureau of Science, Manila, P. I.)

One plate

INTRODUCTION

Although this investigation deals primarily with the value of certain raw materials which are available for the manufacture of brick and natural cement at the Iwahig penal colony, many of the results obtained and the principles discussed are universal, as well as local, in their significance and value. This is especially true of the data on the manufacture of natural cement by the so-called artificial process.

Results obtained by using fine coral sand as the calcareous material, while especially interesting to this country, are none the less valuable to the cement industry in general. They show the economic possibilities not merely of the Iwahig sand, but also of vast resources of similar coral and calcareous sands which heretofore have been practically overlooked by cement producers although already ground fine by natural forces. The artificial method of manufacturing natural (or Roman) cements is comparatively new, although advocated by A. V. Bleininger[1] many years ago as a practical method of overcoming the lack of uniformity in the setting and hardening properties of natural cements.

BRICK MANUFACTURED AT IWAHIG

The history of the manufacture of brick at the Iwahig penal colony shows that the industry was started at the suggestion of Governor Evans. He had experience with brick making at Bontoc, and believed that successful results could be obtained with the clay located a short distance from the colony on the banks of Iwahig River. The Iwahig bricks are made from an alluvial clay obtained near the junction of Malatgao and Iwahig Rivers adjacent to the penal colony. At first, the clay was pugged by a homemade mill turned by a carabao, and the bricks were molded by hand. Now, the clay is taken directly

[1] *Bull. Geol. Sur. Ohio* (1904), 4, 186.

from the ground, mixed with water, and compressed in molds by an animal-power Henry Martin machine. The clay is taken from not less than half a meter below the surface to exclude loam as much as possible, and water is added until a mud ball dropped 45 centimeters will flatten but not crack. No sand is used except for the purpose of sanding the molds so that the green bricks can be removed without difficulty. The bricks are "hacked" as soon as they are dry enough to withstand handling, and finally they are burned in a kiln 45 meters long, 3 meters high, and 2.5 meters wide. Wood fuel is used, and a white heat is maintained for a continuous period of at least twelve hours.

The appearance of the finished product is shown by bricks 1 and 2 in Plate I, fig. 1. No. 1 shows the appearance of the cut surface which, owing to the extreme stickiness of the clay when pugged to the consistency practiced at Iwahig, is deeply pitted and ruptured. The sanded sides shown by brick 2 are fairly smooth, but the white coral sand used for sanding the molds gives the brick a very unpleasing appearance. Also, since the sand is highly calcareous, it is converted into caustic lime which, upon subsequent hydration, slakes and, in expanding, destroys the original smoothness of the surfaces. Also, there is some pitting and abrasion due to the slaking of nodules of lime beneath the surface. It is suggested that the use of molding sand might be avoided and the appearance of the brick improved in consequence if the molds were merely dipped in water instead of being sanded.

The physical properties of bricks 1 and 2, which are given in Table I, are characterized by excessive porosity, poor strength, and high absorption.

TABLE I.—*Physical properties of the brick manufactured at the Iwahig penal colony.*

Item.	Brick.	
	No. 1.	No. 2.
Dimensions in centimeters	20.3×9.2×5.4	20.5×9.7×5.5
Weight in grams (dry)	1,731	1,883
Apparent density (weight/ volume of brick)	1.69	1.71
Specific gravity	2.91	2.94
Absorption of water in per cent	20.61	20.22
Modulus of rupture:		
Transverse strength in pounds	1,050	970
Distance between supports in inches	6.0	6.0
$3Pl/2bd^2$	339	274
Crushing strength in pounds per square inch	779	701

It was thought that a study of the physical and chemical properties of the clay might reveal a practicable method of improving the quality of the brick, and finally at the suggestion of the Director of the Bureau of Science a representative sample was forwarded to the Bureau of Science.

The clay, which is a dirty brown in color and lightly specked with white particles, many of which prove to be grains of coral sand, was first subjected to a chemical examination. The results obtained are recorded in Table II.

TABLE II.—*Chemical characteristics of Iwahig clay (dried at 110° C.).*[a]

ULTIMATE CHEMICAL CONSTITUENTS.

Constituent.	Per cent.
Loss by ignition	10.70
Total silica (SiO_2)	42.16
Soluble silica	9.40
Alumina (Al_2O_3)	24.26
Ferric oxide (Fe_2O_3)	13.90
Calcium oxide (CaO)	6.40
Magnesium oxide (MgO)	0.90
Sodium oxide (Na_2O)	1.41
Potassium oxide (K_2O)	0.10
Sulphur trioxide (SO_3)	0.20
Carbon dioxide (CO_2)	....
Total fluxes	22.75
RATIONAL ANALYSIS.	
Feldspar	31.38
Quartz	21.02
Clay substance, about	42.00

[a] Analyzed by F. Peña, chemist, Bureau of Science.

The high content of iron and calcium oxide and the low content of silica indicate that the clay has little or no value for the manufacture of hard-burned ware, such as paving brick. Experiments showed that it burned best at a temperature of about 1,050° C. Stiff-mud briquettes, burned at this temperature in an oxidizing atmosphere, showed a tensile strength of about 230 pounds per square inch and were of an agreeable brick red.

Except for the few particles of coral, the clay contains very little sand that is visible to the naked eye. It is easily pulverized, and for best results the nodules of coral should be disintegrated or separated from the clay by sifting or elutriation although the clay does not contain more than 1.2 per cent of such material.

The round ruptured spot near the top of brick 5 and the cracks on the surface of brick 6, as seen in Plate I, fig. 1, show the undesirable effects of nodules of calcareous material in the clay. For

brick 7, the pulverized clay was screened through a 30-mesh sieve and the surfaces remained free from rupture.

Ground until no residue remains upon the 20-mesh sieve, or finer, the clay is easy to pug, and when mixed with about 24 per cent of water produces a stiff mud which is easy to mold by hand or to express smoothly through an ordinary brick die. The addition of more water tends to produce a soft mud which is too sticky and too lean to mold well in any single process. If molded by pressure in the semidry or dry state, the brick disintegrates with even ordinary handling or it cracks and warps while drying or burning. The hand-molded, stiff-mud bricks dry fairly rapidly, and in so doing shrink about 8 per cent and develop a tensile strength of 133 pounds per square inch; but better density, strength, and appearance can be obtained by first molding the stiff mud by hand or by expression, and after most of the shrinkage has taken place re-pressing it at a pressure of about 1,000 pounds per square inch.

TABLE III.—*Physical properties of bricks produced from Iwahig clay by different processes of manufacture.*

Item.	Brick.		
	Average of Nos. 1 and 2 made at Iwahig.	No. 3.	No. 4.
Process of molding	(a)	(b)	(c)
Dimensions in centimeters	20.3×9.5×5.4	19.4×9.4×5.4	20.6×9.9×6
Weight in grams (dry)	1,807	1,821	2,153
Apparent density (weight/volume of brick)	1.70	1.82	1.80
Specific gravity	2.93	2.82	2.83
Absorption of water, per cent	20.42	16.63	15.54
Modulus of rupture:			
Transverse strength in pounds	1,010	2,250	2,460
Distance between supports in inches	6.00	6.00	6.00
$3Pl/2bd^2$	307	648	656
Crushing strength in pounds per square inch	750	1,244	1,021
Total shrinkage, per cent		7.6	10.00

[a] Pressed soft mud. [b] Re-pressed stiff mud. [c] Stiff mud molded by hand.

There is not much difference between the handmade and the re-pressed bricks except in appearance; both products are much better than the brick manufactured at Iwahig.

Bricks 3 and 4 in Plate I, fig. 1, represent the product obtained by the best methods of manufacturing brick with Iwahig clay. Both were molded by hand in the condition of stiff mud, but No. 3 was re-pressed at a pressure of 3,000 pounds per square

inch after the clay had become sufficiently dry. Their physical properties are recorded in Table III, which for the purpose of ready comparison includes the corresponding average values of the Iwahig product.

The appearance and properties of brick 3 are those of the best product that can be manufactured at Iwahig, unless a suitable clay for admixture can be obtained. It is unquestionable that a brick with good color, smooth surfaces, clean sharp edges, and sufficient strength and density to meet the requirements of ordinary construction work could be obtained. For moderate demands, a brick having the above qualifications would also be good enough for face brick. To produce such bricks on a commercial scale, the clay should be ground fine enough to eliminate all danger from free lime, pugged and molded in a stiff-mud brick machine, and then re-pressed after the bricks had dried until most of the shrinkage had taken place. The same process of manufacture could be utilized to produce common floor and roofing tiles and terra cotta merely by changing the dies. The unit cost of manufacture should be no greater than it is at present.

However, for reasons which are given in the following pages, the Iwahig clay can be utilized to better advantage with the available fine-grained coral sand for the manufacture of natural (or Roman) cement. And since the natural cement can be made to serve equally well as, or better than, the brick for most purposes, the manufacture of natural cement is probably better economy than even an improved manufacture of brick.

While, from the standpoint of efficiency as a structural material, Portland cement ranks higher in order of merit than natural, or Roman cement, of which Rosendale is a type, yet for many purposes natural cement is perfectly suitable in point of strength, and for such purposes its considerably lower cost makes it more desirable than Portland cement.

NATURAL (OR ROMAN) CEMENT MANUFACTURED AT IWAHIG

A previous contribution from this laboratory [2] suggests that the present commercial and economic conditions of these Islands favor the manufacture of what may be called an artificial Roman cement. The necessity of regulating the composition is shown by Eckel.[3]

[2] Reibling, W. C., and Reyes, F. D., *This Journal, Sec. A* (1912), 7, 147.

[3] Eckel, Edwin C., Cements, Limes, and Plasters. New York City (1905), 198–199.

The work of the Bureau of Science on materials from Naga, Cebu,[4] demonstrated the possibility of manufacturing good natural cement with a cementation index as high as 2.47 from the available coralline limestones and siliceous clays. The coral sand at Iwahig requires very little grinding.

The Iwahig sand is a white, powdery material, consisting almost entirely of comminuted coral and shells. A slight residue of dark-colored grains apparently fragments of ferromagnesian minerals is obtained upon panning. The greater part of the sand which was used in the following experiments was taken from Canagaran Beach. The sand on this beach is very clean, and the deposit extends for 5 kilometers along the shore. It is estimated that there is available for each linear kilometer of beach about 15,000 cubic meters of clean sand above the low-tide level. The remainder of the sand came from the beach at Bancaobancaoan near Iwahig, where it is estimated that a quantity of 50,000 cubic meters could be obtained by dredging in shallow water. There are available, near Iwahig, at least 125,000 cubic meters of this sand. The physical and chemical characteristics of the Iwahig sand are given in Table IV.

TABLE IV.—*Characteristics of dry Iwahig coral sand.*

Ultimate chemical composition.[a]		Granularimetric analysis.			
Constituent.	Per cent.	Sieve No.	Size of mesh in mm.	Per cent retained on sieve.	Per cent passing through sieve.
Loss by ignition	44.40	20	0.92	0.10	99.90
Silica (SiO_2)	1.18				
Alumina		30	0.56	0.16	99.84
Iron oxide (R_2O_3)	1.08				
Calcium oxide (CaO)	48.00	40	0.47	0.20	99.80
Magnesia (MgO)	2.46				
Sodium oxide (Na_2O)	1.80	60	0.28	0.28	99.72
Potassium oxide (K_2O)	0.16				
Sulphur trioxide (SO_3)	0.72	100	0.15	16.28	83.72
Chlorine (Cl)	0.37				
Salt (NaCl)	0.61	200	0.07	74.44	25.56

[a] Analyzed by F. Peña, chemist, Bureau of Science.

The data in Table IV show that the sand, in its natural state, is nearly fine enough to use as ground limestone in a cement factory; that the sand contains about 86 per cent of calcium carbonate and 5 per cent of magnesium carbonate; and that

[4] Reibling, W. C., and Reyes, F. D., *This Journal, Sec. A* (1914), 9, 127.

deleterious constituents are not present in sufficient quantities to cause any undesirable effects. In short, the sand is a very efficient calcareous raw material for the manufacture of either Roman or Portland cement. However, because the Iwahig clay is too low in silica and too high in alumina and iron oxide to produce a mixture which will meet the requirements of the Portland cement industry, the only commercially feasible plan for utilizing this sand is the manufacture of a natural cement.

The data in Table V show the composition of the four natural cement mixtures which were prepared for burning. In each instance, the sand and clay were thoroughly dried and then pulverized until 98 per cent passed through the 100-mesh sieve.

TABLE V.—*The composition of the four natural cement mixtures prepared from Iwahig clay and sand.*

Material.	Parts by weight.		Chemical constituents in per cent.					Cementation index. [a]
	Sand.	Clay.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	
Iwahig clay	0	1	42.16	24.26	13.90	6.40	0.94	
Iwahig sand	1	0	1.18	0.68	0.40	48.00	2.46	
Mixture 1	2	1	14.84	8.54	4.90	34.13	1.95	1.47
Mixture 2	7	4	16.08	9.25	5.31	32.87	1.91	1.69
Mixture 3	7	5	19.01	10.51	6.03	30.66	1.90	2.12
Mixture 4	12	5	13.23	7.61	4.37	35.76	2.01	1.24

[a] $\frac{2.8 \times \%SiO_2 + 1.1 \times Al_2O_3 + 0.7 \times Fe_2O_3}{\%CaO + 1.4 \times \%MgO}$

These mixtures were each pugged with water to the consistency of stiff mud, molded into 9-inch bricks, and when dry burned at a temperature of about 1,000°C. in an experimental brick kiln. The resulting clinkers disintegrated more or less when exposed to the air for several days, and when moistened with water crumbled to pieces within twenty-four hours. This fact and the microscopic phenolate test described elsewhere [5] showed that considerable free lime was present. However, the free lime was not sintered, and therefore it slaked as soon as exposed to water. On the other hand, as the burned bricks contained no carbon dioxide, the raw materials had been thoroughly calcined.

Mixture 3 slaked the least and 4 the most. In all probability, better results would have been obtained by burning the mixtures

[5] White, Alfred H., *Journ. Ind. & Eng. Chem.* (1909), 1, 5; Reibling, W. C., and Reyes, F. D., *This Journal, Sec. A* (1910), 5, 367–419.

with the highest cementation index at a low temperature and vice versa. However, there was no opportunity to make other than a rather preliminary examination of the possibilities of these raw materials in the artificial process of manufacture.

The burned bricks were soft and easy to grind. They were aërated for twenty-four hours in the laboratory, pulverized, and tested for fineness, specific gravity, soundness in steam, and setting properties. The results obtained are recorded in Table VI.

TABLE VI.—*Physical characteristics of the four artificial Roman cements.*[a]

Test.	Results.			
	No. 1.	No. 2.	No. 3.	No. 4.
Fineness:				
Per cent through the 100-mesh sieve	97.4	97.6	96.6	98.2
Per cent through the 200-mesh sieve	78.4	80.2	78.6	83.6
Specific gravity dried at 110° C.	2.84	2.88	3.02	2.87
Soundness, steamed 5 hours	sound	sound	sound	sound
Time of initial set in minutes:				
Without plaster	[b] 160(37)	95(37)	105(39)	heats up
With 1.0 per cent plaster	90(37)	65(36)	15(37)	20(37)
With 2.0 per cent plaster	40(37)	40(35)	15(34)	25(36)
With 2.5 per cent plaster	25(35)	25(34)	5(34)	35(36)

[a] Tested according to the 1912 United States Specification for Portland cement.

[b] The figures in parenthesis give the percentage of water required for a paste of normal consistency.

Standard specifications do not require that natural cements pass the accelerated tests for soundness, but all of these cements remained sound when subjected to the regular steaming test for Portland cements. The nonplastered, nonseasoned cements failed to harden sufficiently within twelve hours to bear the weight of the heavy Gilmore needle without showing the mark of the point. On the other hand, all of the cements gained their final set in less than ten hours, which must be considered very satisfactory for natural cements tested by the Gilmore method.[6]

The setting properties of these cements were again tested after they had aërated for eighteen hours, spread out on paper in layers about 1 centimeter thick. The results obtained are given in Table VII.

As anticipated, seasoning had the desired effect of retarding the initial set and quickening the final set, and all of the plastered cements set in a very satisfactory manner.

[6] Cf. Reibling, W. C., and Salinger, L. A., *This Journal, Sec. A* (1908), 3, 137–185.

TABLE VII.—*The setting properties of cements 1, 2, 3, and 4 aërated for eighteen hours.*

Mixture No.	Per cent plaster added.	Per cent water required for normal consistency.	Time of setting in minutes.	
			Initial.	Final set.
1	----------	35	50	600
	1.0	34	50	440
	2.0	34	45	340
	2.5	34	35	285
2	----------	35	80	600
	1.0	34	55	480
	2.0	34	50	400
	2.5	34	45	480
3	----------	35	70	500
	1.0	34	55	140
	2.0	35	50	110
	2.5	35	55	90
4	----------	40	115	600
	1.0	37	80	540
	2.0	37	70	525
	2.5	37	70	510

Unfortunately, there was not enough material left to test the hardening properties of cements 3 and 4, but the data in Table VIII show the excellent results obtained with 1, not seasoned, and 2, aërated for eighteen hours. Each strength recorded is the average of four tests; and it is worthy of mention that the differences between the average and the maximum and minimum results were remarkably small compared to the variations usually obtained with Portland cements.

TABLE VIII.—*Hardening properties of natural cements 1 and 2, containing 1 per cent of plaster.*

Test.	Results.		Requirements of specifications.[a]
	Cement 1, not seasoned.	Cement 2, aërated 18 hours.	
Tensile strength in pounds per square inch:			
Neat mortar—			
1 day in moist air	91	94	----------
1 day in moist air, 6 days in water	256	233	150
1 day in moist air, 18 days in water	296	295	(b)
1 day in moist air, 27 days in water	313	306	250
1 day in moist air, 90 days in water	370	336	(b)
1:3, Ottawa-sand mortar—			
1 day in moist air, 6 days in water	144	141	50
1 day in moist air, 18 days in water	182	194	(b)
1 day in moist air, 27 days in water	214	237	125
1 day in moist air, 90 days in water	317	242	(b)

[a] *Am. Soc. Test. Mats.* (1912). [b] Not given.

A mixture of the four cements in equal proportions aërated for eighteen hours, molded into neat briquettes, and exposed to the atmosphere in the laboratory gave the following average tensile strength in pounds per square inch:

7 days=138 pounds per square inch.
28 days=168 pounds per square inch.
154 days= 85 pounds per square inch.

The compressive strength, developed by 2-inch cubes of neat and sand mortars of the same mixtures, is given in Table IX.

TABLE IX.—*Compressive strength of cements 1, 2, 3, and 4, mixed.*

Age of 2-inch cubes.	Compressive strength in pounds per square inch.	
	Neat mortar.	1:3 Ottawa-sand mortar.
28 days in air	1,989	1,133

The strength developed by these cements far exceeds the requirements of the standard specification for natural cements, and there is little doubt but that a more thorough study would secure still better results.

Plate I, fig. 2, is a photograph of part of the Bureau of Science exhibit of calcareous-siliceous resources at the 1914 Philippine Exposition. It shows the Iwahig raw materials and the clinker, cement, steamed soundness pats, and pressed concrete bricks which they produced.

CONCLUSIONS

The Iwahig penal colony could convert its brick plant at very little extra expense into a cement factory which could produce a good grade of natural cement. The brick press at the colony would serve to mold the cement mixture and the kiln to burn the resulting bricks. It would be necessary to install only pulverizers, and as both the raw materials and the clinker require very little grinding this would not be expensive. The cost of manufacture would be much less than for the clay bricks. Neither the molding nor the burning requires great care, and it is only necessary to maintain a temperature of 1,000°C. in the kiln for from three to four hours, whereas with the clay bricks a temperature of about 1,050°C. must be maintained for twelve or more hours.

Enough work has been done to prove the feasibility of the commercial manufacture of natural cement at Iwahig and to show that the product will meet the requirements of many kinds of concrete construction work. Natural cement can be used to advantage mixed with Portland cement. A mixture containing 9 parts of natural and 1 part of Portland cement will gain strength more rapidly than natural cement and may be employed where early removal of the forms is desirable. It is probable that by further study the raw materials could be utilized to produce much better natural cements than those described in the preceding pages, and a thorough investigation should be made before a cement plant is installed.

ILLUSTRATIONS

PLATE I

FIG. 1. Bricks manufactured from Iwahig clay:

Nos. 1 and 2 manufactured at Iwahig by the soft-mud, direct-press process.

Nos. 3 and 4 manufactured at the Bureau of Science by stiff-mud processes.

Nos. 5 and 6 show effects of nodules of calcareous material in the clay.

No. 7 shows smooth surfaces obtained when nodules of calcareous materials are pulverized.

No. 8. Floor tile.

2. The raw materials and natural cement products obtained by the artificial process of manufacture.

Fig. 1. Good and bad bricks manufactured from Iwahig clay.

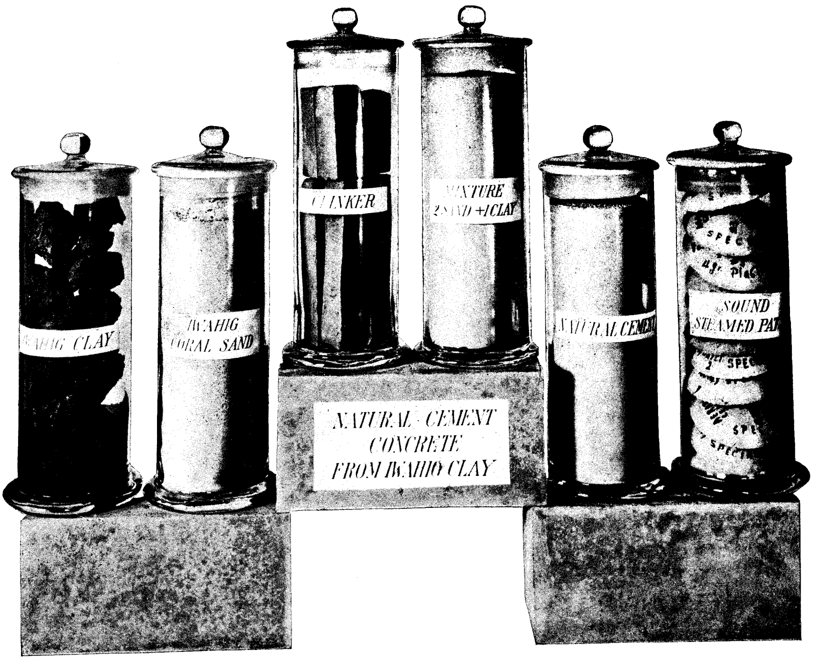

Fig. 2. Iwahig raw materials and the natural cement products obtained from them.

PLATE I.

BOOK CARD

AUTHOR Reibling, W.C.

TITLE Natural Cement versus Brick.

SIGNATURE	ISS'D	RET'D
S. D. Yang	[illegible]	[illegible]

Form 176 (2-10-17) 20M